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Digital Image Compression Using Hybrid Technique based on DWT and DCT Transforms

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Abstract— Nowadays, Digital Image Compression has become an indispensable part for storage and transmission. Compression is necessary for storing and transmitting image because of limited storage space and low bandwidth capacity. Wireless Image Compression is embedding scheme for reduction of image size so that it require less disk space and faster attachment possible in communication. Research issues in Image Compression are in terms of image quality of decompressed image on higher compression ratio and robustness against visual attacks. In this paper, a hybrid technique using Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) is proposed. Hybrid DWT and DCT based Compression technique to obtain increased quality of decompressed image as compared to DCT and DWT individually. The proposed technique is based on embedded process in which DCT is embedded in four level DWT. A good Compression ratio is achieved with increase in PSNR, which shows visually improved quality.

Keywords—Compression Ratio, Discrete Cosine Transform, Discrete Wavelet Transform, Image Compression, Peak Signal to Noise Ratio, Mean Square Error.

I. INTRODUCTION

The image usually consists of enormous amount of data and requires large number of space in the memory. If more number of data is required for transmission then it takes too much time to transmit data from one place to another. Thus by using image compression techniques the time consumption can be reduced. The goal of image compression is to minimize the information redundancy with the objective of reducing archiving costs and transmission bandwidth [1]. The image can be compressed when the correlation between one pixel and its neighbor pixels is very high, or the values of one pixel and its adjacent pixels are very similar.The objective is to reduce redundancy of the image data in order to store or transmit data in an efficient form. It helps in reducing the no. of bytes without making any changes in its original image, so that it will take less time, and less hard disk space to send a data from one place to another [2]. There are two types of image compression: Lossless Image Compression and Lossy Image Compression. The Lossless compression technique is one of the most suitable image compression techniques where compressed image will be same as that of original image, but the Compression Ratio is very low, i.e. there is not much reduction in file size. Lossy compression is used when there is loss of redundant data from image and user can tolerate some difference between original and reconstructed image. It transforms and simplifies the data in a much larger reductions in file size which leads to a good Compression Ratio as compared to Lossless Compression techniques. But it can distort the image quality due to the higher reduction in file size. In particular, we focus our attention on the lossy compression. The use of transform techniques is recommended to this type of compression [3]. The purpose of research is to find out a transformation based compression approach which have low computational complexity and able to concentrate the signal energy in the smallest number of parameters. There are Discrete Wavelet Transform (DWT) and Discrete Cosine Transform (DCT) based compression techniques which have properties like reversible, unitary, symmetric and constant energy.

In order to get the advantage of both DCT and DWT, a hybrid scheme based on DWT and DCT scheme has been proposed in this paper.To develop a compression system with DWT transform, four parameters are important to take into consideration: test image, wavelet function, number of iterations and calculation complexity. As compared to [1], we have increased number of iterations equal to four in our work and we have applied 2D DCT of size 8x8 on detailed images.

This paper is organized as follows: We first review the compression techniques which includes DCT and DWT, and then propose the new hybrid approach which is a combination of DCT and DWT, and compare the results obtained with proposed technique and that of DCT and DWT individually. Mean Square Error and PSNR is to be calculated and compared. The idea of applying two transforms is based on the fact that the combined transforms could reduce the drawback existing in each transform.

II. RELATED WORKS

Image compression has many practical applications because of large data storage, transmission and retrieval of images for medical processing, documents,videoconferencing and various multimedia applications. Salam Benchikh and Michael Corinthios [1] describes an image compression technique based on DCT and DWT. They applied 3 level decomposition of DWT. The two-dimensional DCT is applied only on approximation image resulting from iteration 3. For the nine detail images, they applied two thresholds for compression. A.H.M. Jaffar Iqbal Barbhuiya, Tahera Akhtar Laskar, K. Hemachandran [5] decribed the image compression techniques using DCT and DWT. A new algorithm has been proposed on Image Compression using DWT and Inverse DWT based on color image of different image formats. Navneet Kaur Aulakh and Er. Yadwinder Kaur [6] decribed DCT, DWT and Hybrid (DCT-DWT) transforms utilizing stenography process mutually to compression an image. Simulation results demonstrate, that hybrid (DWT-DCT) along with steganography performs superior than individual JPEG-based DCT and DWT algorithms in terms of their performance measurement: peak signal-to-noise ratio (PSNR) and visual perception at advanced compression ratio. Ch.Sathi Raju and D.V.Rama Koti Reddy [8] decribed a hybrid DCT and DWT compression method to capitalise the advantages of both the techniques. The method involves in generating color data of the white band and narrow band images in an intermediate format and then generating the decompressed image. The quality of the decompressed image is evaluated in terms of mean square error (MSE), signal to noise ratio (SNR) and peak signal to noise ratio (PSNR). Sukant Vats, Geetanjali Rathee [9] described compression can be achieved by sub-band decomposition analysis. Wavelet based processing solves contradiction of time and frequency resolution as compared to Fourier transform. It also overcomes the problem of blocking artifact at high frequency resolution which is observed in Discrete Cosine Transform (DCT).

III. TRANSFORMATION TECHNIQUES

In the following, we briefly review the DCT and DWT transforms. We then present our hybrid DCT-DWT technique. Discrete cosine transform and discrete wavelet transform have been used in many digital signals processing application and specifically in image compression.

A. *Discrete Cosine Transform*

The Discrete Cosine Transform (DCT) attempts to decorrelate the image data. After decorrelation each transform coefficient can be encoded independently without losing compression efficiency [10]. DCT utilizes cosine functions, it transform a signal from spatial domain to frequency domain. The DCT characterize an image in the form of sinusoidal signal of varying amplitudes and frequencies. For an ordinary image, nearly all part of the visually critical information of an image are concentrated in few coefficients. After processing of coefficients, these are normalized by quantization process using quantization table. The estimation of quantization is inversely proportional to the quality of reproduced image, better mean square error and good compression ratio. Quantization, as a core module effectively reduces the visual redundancy and is the only operation that introduces distortion [13]. In a lossy compression approach, the less significant frequencies components are discarded during quantization, and essential frequencies components that remain are make use of to recover image in decomposition process [11]. After quantization, the quantized coefficients are adjusted in a zigzag way as shown in figure 1 for further compressed by an proficient coding algorithm.

Firstly, the image is broken into 8x8 sub blocks. DCT is applied on each block from the left to the right and from the top to the bottom. Then, quantization is applied for compression process, and data are stored following a specific process to reduce the information. And to reconstruct the compressed image we apply IDCT transform [1]. The coefficients of DCT transform are computed using equation 1.

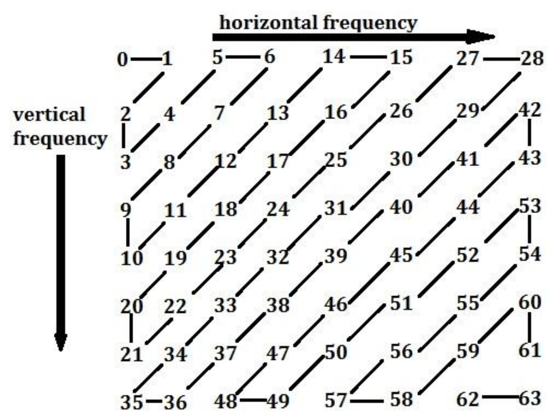


Figure 1 Zig-Zag sorting order of DCT

$$D(i,j)=\frac{1}{\sqrt{2N}}C(i,j)C(i,j)\sum_{x=0}^{M-1}\sum_{y=0}^{N-1}p(x,y)\cos\left[\frac{(2x+1)i\pi}{2M}\right]\cos\left[\frac{(2y+1)j\pi}{2N}\right]$$

……(1)

where, *p(x,y)* is an input matrix image *NxN*, *(x,y)* are the coordinate of matrix elements and *(i,j)* are the coordinate of coefficients, C(u) is given by equation 2

$$C(u)=\begin{cases} 1/\sqrt{2} & if \quad u=0 \\ 1 & if \quad u>0 \end{cases}$$

....(2)

The reconstructed image is computed by using the inverse DCT (IDCT) which is given by equation 3

$$p(x,y) = \frac{1}{\sqrt{2N}} \sum_{i=0}^{N-1}\sum_{j=0}^{N-1} C(i,j)C(j)D(i,j)\cos\left[\frac{(2x+1)i\pi}{2N}\right]\cos\left[\frac{(2y+1)j\pi}{2N}\right]$$

…..(3)

The pixels in black and white images are arranged from 0 to 255 with the step of 1, where 0 refers to a pure black and 255 refers to a pure white. Since DCT is used for pixels arranged from -128 to 127, then for each input pixel we subtract 128. The block diagram of DCT is shown in figure 2.

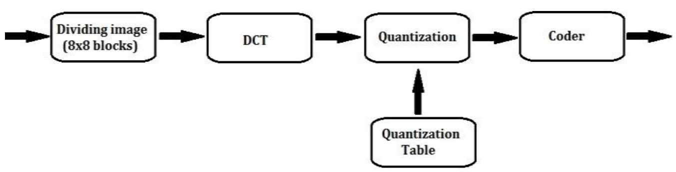


Figure 2 Block diagram of DCT

The block diagram of IDCT is shown in figure 3.

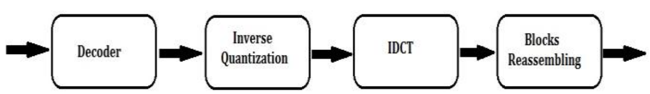


Figure 3 Block Diagram of IDCT

B. Discrete Wavelet Transform

A wavelet is a mathematical function used to divide a given function or continuous-time signal into different wave signals. DWT mainly used in the transformation of a discrete time signal to Discrete Wavelet Representation [12]. It can assign a particular frequency range for each wave signals. All wave signals that match its scale can be analyzed with a resolution. It is the delegation of a function by wavelets given by equation 4.

$$\psi_{a,b}(t) = \frac{1}{\sqrt{|a|}}\psi\left(\frac{t-b}{a}\right), a,b \in R, a \neq 0 \quad …..(4)$$

Where ψ is a function called wavelet, a, is scale function which measure the degree of compression, and b, is a translation function which measures the time location of the wavelet. The wavelet transform can be obtained by digital filtering of the signal, assisted by a series of digital filters of different scales. By sub-sampling the signal and also changing its resolution, the scaling operation can be performed. Images being in the form of matrix can be treated as a sequence of information x[n]. This sequence when processed by the filters in DWT technique and down-sampled by scaling factor 2, gets decomposed into low-frequency l[n] and high-frequency h[n] sub-bands given by Eq. 5 & 6.

$$l[n] = \sum_{k=-\infty}^{\infty} x[k]a[2n-k] \quad ……(5)$$

$$h[n] = \sum_{k=-\infty}^{\infty} x[k]b[2n-k] \quad ….(6)$$

The relationship between the decomposition levels 'M' and the sub-bands 'S' used for processing after the 1st level is given by Eq.5.

$S = 4 + (M-1)*3$ for M=2,3,………. ∞ …. (7)

DWT algorithm gives better Compression ratio and PSNR to get the good quality of input images as compared to DCT [18].

IV. PROPOSED HYBRID TECHNIQUE

The proposed technique is divided into two parts : Image Compression and Image Decompression.

A. Image Compression Using Hybrid Technique

The steps for image compression using hybrid technique are proposed as follows:

STEP 1: The colored original image is first converted into YCbCr Model from RGB Color Model [14]. For Colored Images, we use RGB Color Model. The human eye has different sensitivity to colour and brightness has been proved by medical research. Thus there came about the transformation of RGB to YCbCr.

Y stands for Luminance, Cb stands for Chrominance-Blue; and Cr stands for Chrominance-Red. Luminance is similar to the grayscale version of the original image. Cb is strong in case of the image containing the sky (blue) in most of its parts, both Cb and Cr are weak in case of a colour like green, and Cr is strong in the places where reddish colours appear. According to Medical Research, the eye consists of rods cells which are 120 million in number, are much more sensitive than the cones which are around 6-7 million in number. The rods are sensitive to changes in illumination, while the cones have colour sensitivity. Thus, the human eye is more sensitive to Y component i.e. illumunance rather than the chrominance, or colour components (Cb, Cr). Thus, during compression, it becomes easier to reduce the bit requirement for the colour components, and store the luminance properly.

STEP 2: After conversion of YCbCr Model, the planes are separated as Y Plane, Cb Plane and Cr Plane. The reason for conversion of these planes is that we will able to apply Discrete Wavelet Transform to each of these planes separately.

STEP 3: In Y plane, we apply Discrete Wavelet Transform, First we take a level-1 DWT and separate the DWT approximation and the DWT-details. For the details we apply

Discrete Cosine Transform. Similarly, we take level 2 DWT and again separate the DWT approximation and Details, and apply the DCT to DWT details. Similarly, 4 level decomposition is done in DWT and DCT is embedded in it. Thus, we get Compressed Image.

All these steps can be represented by Flow Chart which is shown in figure 4 and detailed flowchart has been shown in figure 5. This flowchart shows the basic steps used in the hybrid approach.

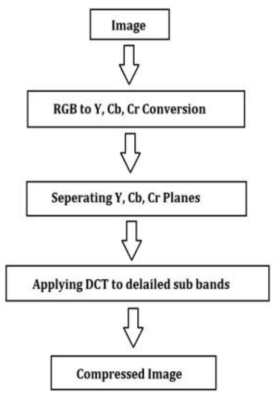


Figure 4 Flow Chart for hybrid approach

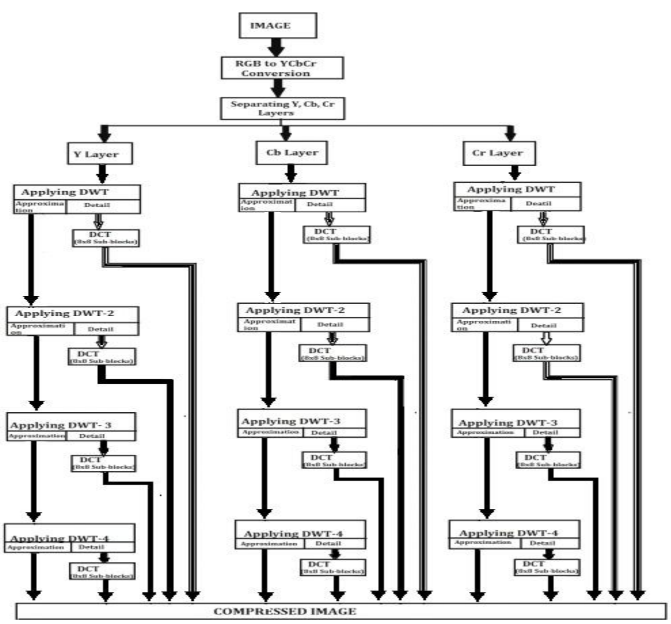


Figure 5 Detailed FlowChart for Hybrid Approach

B. Image Decompression Using Hybrid Approach

Step 1: For Decompression, Inverse Discrete Cosine Transform is applied to the detailed sub-bands of 4th level. Then, IDCT is applied to the 3rd level of DWT. Similarly, to the 2nd and 1st level of detailed DWT.

Step 2: Now, Inverse Discrete wavelet Transform is applied to the 4th level after performing IDCT at 4th level. For the 3rd level, firstly IDCT is performed on the detailed sub bands and then IDWT is performed. Similarly, for 2nd level, IDCT is performed on detail sub bands and then IDWT is performed. And finally for the 1st level, the same procedure is applicable.

Step 3: The IDWT and IDCT operation is performed on all the three planes separately, i.e. on Y plane, Cb plane and Cr plane. Then, all these planes are combined again to get decompressed image in YCbCr Color Model. But, for representation purpose, RGB color Model is accepted. So at last, YCbCr Color Model is converted to RGB color Model.

All these steps are represented by FlowChart as shown in figure 6

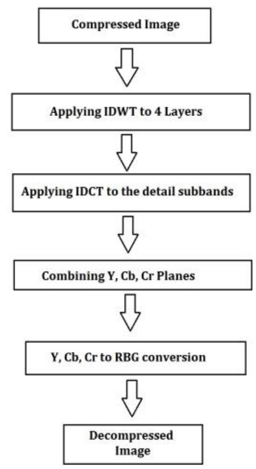


Figure 6 Image Decompression Using Hybrid Approach

V. EXPERIMENTAL RESULTS

A. Test Images

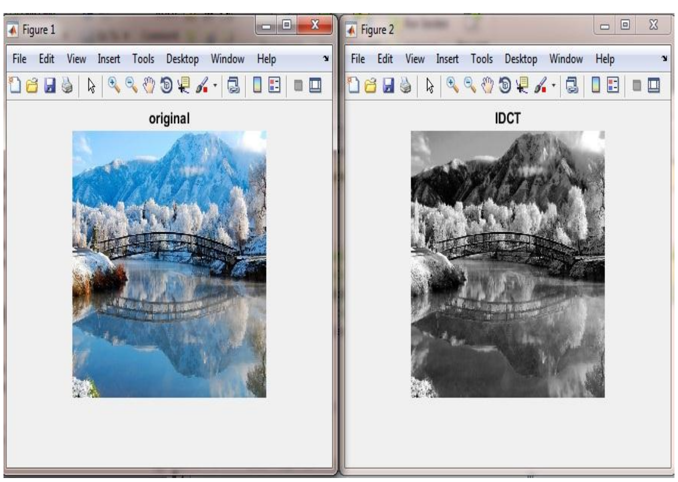
We have taken five test images which are shown in figure 7.

B. Discrete Cosine Transform

The experimental results of discrete cosine transform has been shown in table 1. Here, we have taken five test images and performed our experiments on it.

Table 1

IMAGES	PSNR	MSE
Image 1	4.0409	2.5644e+04
Image 2	2.8978	3.3366e+04
Image 3	10.5528	5.7253e+03
Image 4	1.4330	4.6750e+04
Image 5	1.8079	4.2884e+04



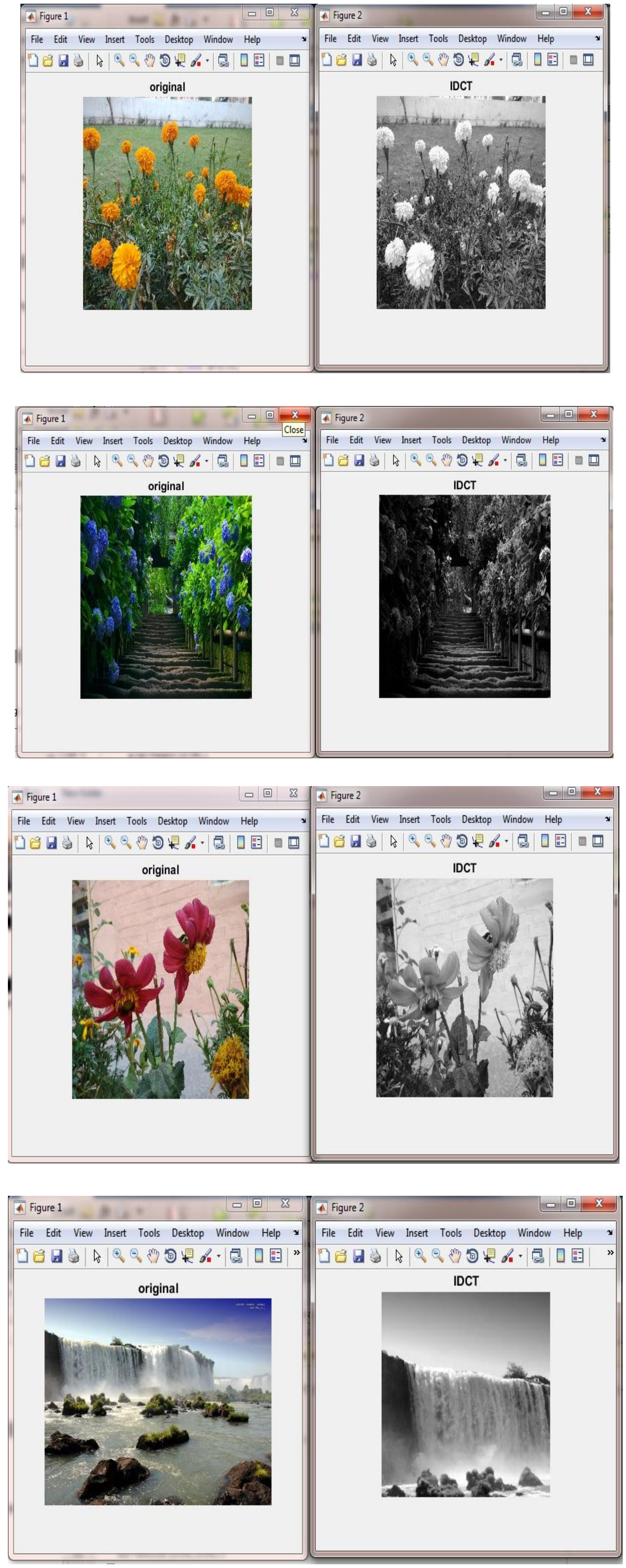


Figure 8 Results of DCT

B. Discrete Wavelet Transform

The experimental results of discrete Wavelet transform has been shown in table 2. Here, we have taken five test images and performed our experiments on it.

Table 2

Images	PSNR	MSE
IMAGE 1	12.3162	3.0586e+04
IMAGE 2	10.9668	1.7266e+04
IMAGE 3	16.2480	1.0420e+04
IMAGE 4	9.6371	2.1560e+04
IMAGE 5	13.8844	2.1487e+04

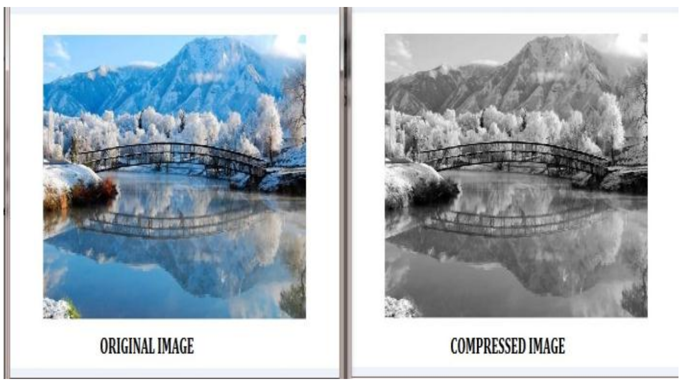


Figure 9 Results of DWT

C. Hybrid Technique using DCT +DWT

The experimental results of Hybrid Technique using DCT+DWT has been shown in table 3. Here, we have taken five test images and performed our experiments on it.

Table 3

Images	**PSNR**	**MSE**	**Compression ratio**
Image 1	**24.6332**	**223.7482**	**16.6526**
Image 2	**19.1634**	**788.3954**	**50.8303**
Image 3	**23.9003**	**264.8818**	**20.5727**
Image 4	**31.0352**	**51.2345**	**44.0828**
Image 5	**27.0122**	**129.3775**	**37.7613**

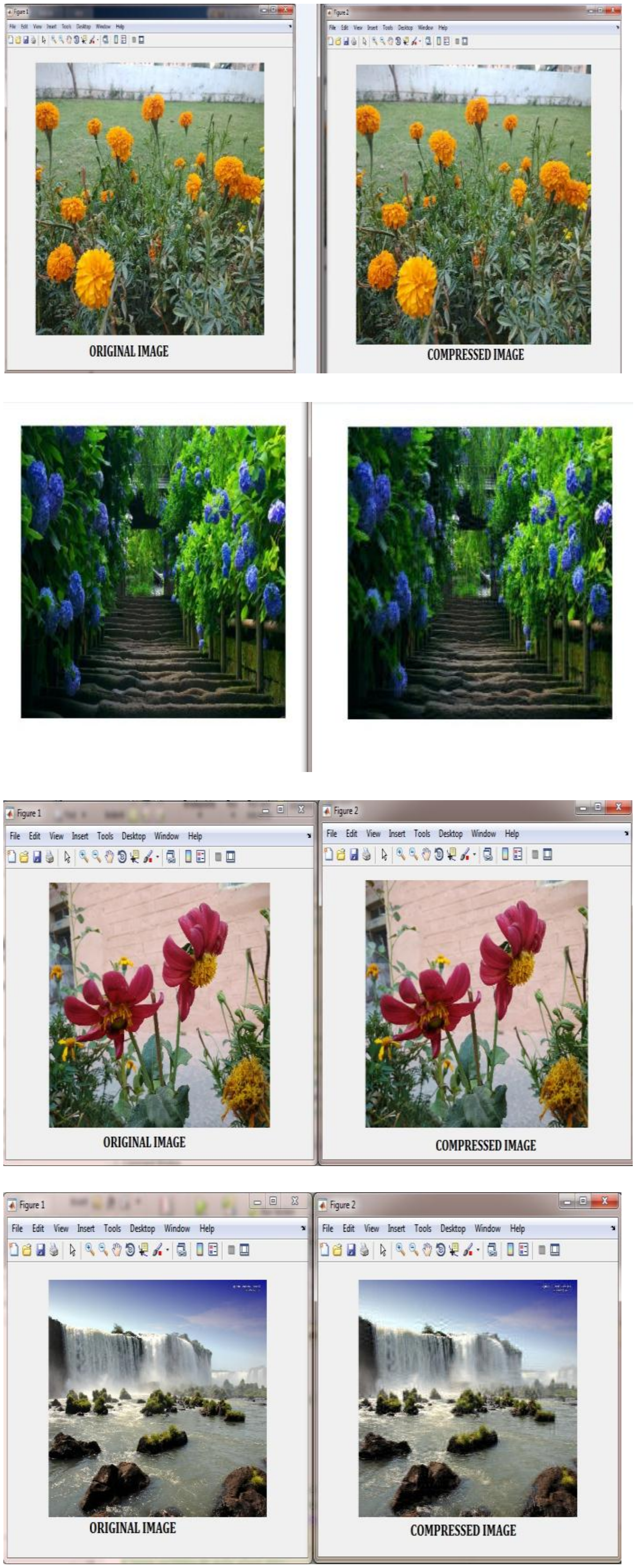


Figure 10 Results of Hybrid Technique

VI. COMPARISON OF DCT, DWT AND HYBRID TECHNIQUE

The comparison of PSNR values of all the three techniques has been shown in figure 11 and data has been represented in table 4.

Table 4

Images	DCT	DWT	Hybrid
Image 1	4.0409	12.3162	24.6332
Image 2	2.8978	10.9668	19.1634
Image 3	10.5528	16.2480	23.9003
Image 4	1.4330	9.6371	31.0352
Image 5	1.8079	13.8844	27.0122

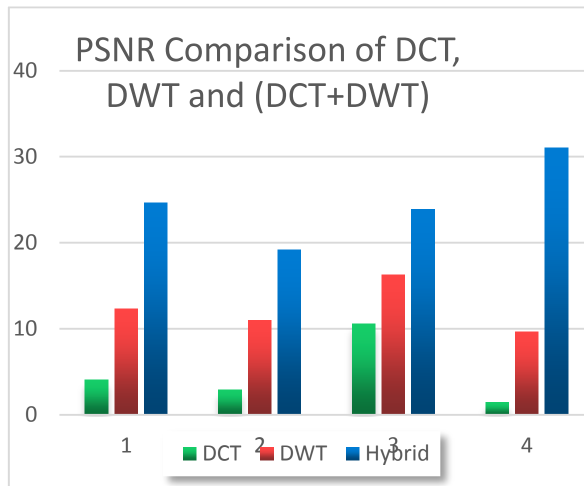


Figure 11 PSNR Comparison of DCT, DWT and (DCT+DWT)

The comparison with MSE for DCT, DWT and Hybrid Technique has been shown in figure 12 and data has been represented in table 5

Table 5

Images	DCT	DWT	Hybrid
Image 1	2.5644e+04	2.3685e+04	223.7482
Image 2	3.3366e+04	1.7266e+04	788.3954
Image 3	5.7253e+04	1.0420e+04	264.8818
Image 4	4.6750e+04	2.1560e+04	51.2345
Image 5	4.2884e+04	2.1487e+04	129.3775

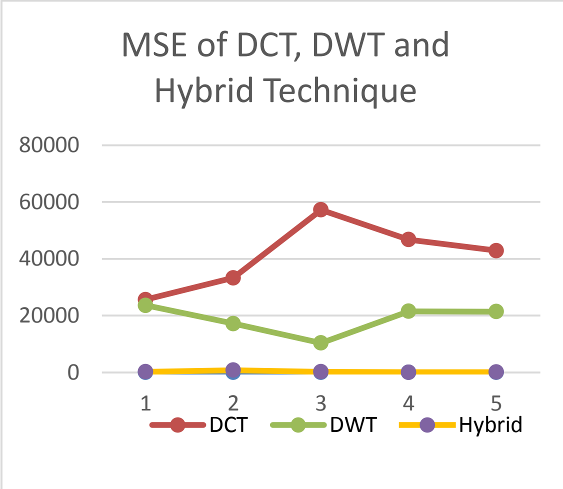


Figure 12 MSE comparison of DCT, DWT and (DCT+DWT)

VII. CONCLUSION

In this research plan, an attempt has been made to study and compare the image compression techniques using DCT and DWT. A new algorithm has been proposed on Image Compression using DWT+DCT. An experimental result has been shown after compressing any color image of different image formats. The most distinguishing feature of using DWT+DCT is that it will not only enable to compress an image but also will help to maintain the quality of the image as it was in its original form, which was hardly possible earlier in other image compression techniques.

From the results it is derived that proposed technique has achieved high Peak Signal to Noise ratio (PSNR) and low Mean Square Error (MSE). MSE is defined as cumulative square of the difference between original and reconstructed image. PSNR signify visual quality against loss due to embedding for compression. So proposed technique have better visual decompressed image as compared to DWT and DCT based compression. Also as compared to DCT and DWT alone MSE is quite low because of which a good visual quality is achieved.

This proposed Technique works on all types of images with all data formats and gives good visual quality as compared to DCT and DWT.

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